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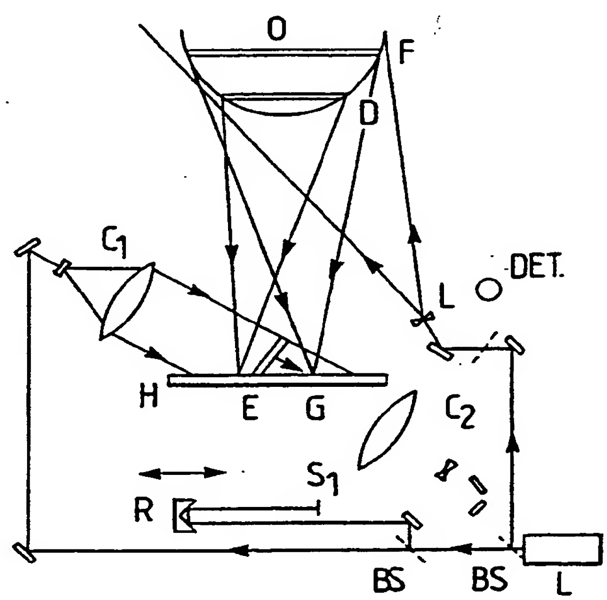
(54) Title: A HOLOGRAPHIC METHOD FOR OBTAINING A QUANTITATIVE LIKENESS MEASURE



(57) Abstract

From a laser (L) is delivered a short pulse, which is divided into an expanded reference beam incident at an angle against a photographic plate (H), and an expanded illumination beam which illuminates a master object (O). The plate is developed to form a holographic image and remounted in the same setting, and a comparison object is brought into the same position as the master object. The plate (H) is illuminated from its opposite side with an expanded short pulse beam antiparallel to the reference beam, light diffracted from the plate image illuminating the comparison object. Light brought back antiparallel relative to the expanded illumination beam is brought to a detector (D), the time spectrum therefrom indicating the degree of likeness between the master object and the comparison object.

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A holographic method for obtaining a quantitative likeness measure

There exist well established methods to use holography for the measurement of vibrations and deformations [1, 2]. Within some limits it is also possible to measure dimensions by holography e.g. by using lasers with two different wavelengths. However, this method has not reached general industrial uses mainly beacuse it is time consuming as it is based on producing a new hologram for each measurement and then evaluated by counting a number of fringes in the holographic image.

A new method was introduced by us some years ago in which the hologram is produced with an ultrashort laserpulse (e.g. a pulsetime of one picosecond which is equal to a length of 0,3 mm). With this method only one bright fringe is produced which simplifies an automated evaluation. Still, however, a new hologram has to be produced for each measurement [3, 4, 5].

In accordance with the invention, an ultrashort laserpulse is used to produce a hologram e.g. of an accurate product, the master. Then the product to be tested is illuminated with the holographic image of the master. For this purpose the hologram is reconstructed, again using an ultrashort laserpulse. The result is that out from the product is emitted a pulse the length of which can be used as a mesure of the difference in shape between master and test object. If there is no difference, the pulse length is in principle equal to that of the original pulse.

One advantage is that only one hologram (that of the master) has to be made. Any number of products may then be compared against this hologram. Another advantage is that the result is not in the form of a fringe pattern that has to be evalua-

ted more or less manually, but just only a signal the length or form of which may Le measured. This signal represents not just one measurement but thousands of measuring points are inspected and compared within a time span of a few nanoseconds.

Thus our technique appears to have the potential to become of great value as an industrial method to test if products have such dimensional accuracy that they are to be accepted or not.

Problems are that, at the moment, picosecond lasers and detectors are complicated and expensive devices. However, there is such a fast development in these fields that we believe that within a near future the method will become both practical and economical.

Fig 1 and Fig 2 show the respective setups for recording and reconstruction in an exemplary embodiment.

Description of an example.

First Step.

A laser (Fig. 1) produces a laser beam consisting of one picosecond pulse. A beamsplitter (BS) reflects part of the beam via two mirrors to a negative lens, which widens the beam so that it illuminates the whole object (O). This beam is named the object beam.

The other part of the beam passes through the beamsplitter and travels via two mirrors to a collimator (C_1) consisting of a negative plus a positive lens which widens this beam so that is illuminates the whole hologram plate (H). This beam is named the reference beam. S_1 represents a stop used to block the beam used for the second step.

Because the laser produced a picosecond pulse pulse with a length of only 0,3 mm the result of the holographic exposure

will be a Light-in-flight hologram. This means that a recording is produced only of those parts on the hologram plate where the pathlengths of the reference beam and the object beam are equal. Thus, because the reference beam arrives from the left to the hologram plate, a closer part (D) of the object (C) is recorded further to the left (at E) on the holographic plate (H). An object part (F) which is further away will be recorded more to the right (at G) on the plate. After exposure the plate is developed, fixed and dried and finally placed back at exactly the same position as when it was exposed.

The procedure that we have now described represents a holographic recording of the master object, to which other test-objects are to be compared. The master is an object that has been dimensionally very accurately measured and found to be accepted and of good quality.

Second Step.

In the next step testobjects are to be compared to the master to find out if they are to be accepted or rejected. For this purpose both the object beam and the reference beam are shut off by the stops S2, S3, (Fig. 2). Instead the hologram plate is illuminated with a beam (the reconstruction beam) that is antiparallel to the former reference beam and the pathlength of which can be adjusted by moving a reflector (R). Thus, this reconstruction beam, which consists of a picosecond pulse, illuminates the hologram plate from the back side through the collimator C_2, and moves from right to left. As it moves over the plate it first hits the part (G) and by diffraction emits a pulse towards (F), which is a part on the object that is further away. Later on the reconstruktion pulse hits (E) and by diffraction emits another pulse towards (D), which is a part of the object that is closer. Because everything during reconstruction is exactly timereversed as compared to what happened during recording the two pulses will, in the form of diffuse scattered light, arrive at the

detector (DET) corresponding to the expander of the object beam at exactly the same time.

If, however, the object did not have exactly the same dimensions during the recording and the reconstruction phase, then the pulses would arrive at slightly different times and thus the pulse would appear lengthened. Thus, the length of the pulse arriving at (DET) is a measure of the dimensional difference between the recorded and the studied object. A photodetector situated anywhere along the beam (e.g. at DET) could give a signal that tells if the studied test object should be accepted or rejected. The detector could consist of just an ultrafast electronic lightdetector or a slower detector in combination with a Kerr cell, a Pockel cell, nonlinear medium 6, streak camera, autocorrelator or the like.

To find our what part of the object that is displaced, different parts of the object or the hologram plate could be masked.

The detector could also consist of another set up for Light-in-flight recording. In that case the negative lens of the beam expander could be removed and replaced by a second hologram plate with its reference pulse. The image of the test object reconstructed from that hologram would then appear bright if it is identical to the master, but where it differs in shape it would appear dark.

By moving the point of observation away from the position of the removed lens towards or away from the direction of the reference pulse of the second hologram plate, there can be found and measured how much the displaced part has moved in the forward or backward direction respectively.

What is new in our invention is the following:
To expose a hologram of a master object using a picosecond pulse, later with another picosecond pulse project the real

image of this hologram on to another testobject, and to use the resulting pulselength of the scattered light as a measure of the dimensional differences, as a pulsesignal which may be analyzed as to size and form. The simplest analysis is to measure its length, which will always be somewhat broader than that of the laser pulse. It is possible to prescribe a maximum, the exceeding of which means that the product studied is not accepted.

The invention can be used for the control of products against the virtual master created by the hologram plate. It is also possible to establish the degree of symmetry for e.g. a propeller or a turbinerotor, which should present itself exactly alike if rotated by a predetermined angle.

In order to eliminate errors of position of object or illumination or detection when only the degree of identity is sought, it may be appropriate to arrange manipulating apparatus for automatically adjusting the position (in e.g. six dimensions) for which the measured pulse length has a minimum value.

It may be noted that the corner-cube reflector R, which defines the pathlength between the laser and the plate in Fig. 2 is expendable, unless needed in order to obtain proper timing for Kerr-cell shutters or the like in front of detector DET.

For making the original hologram, it is presently preferred to use only one short pulse. Under mechanically stable circumstances, it may be possible to use a plurality of pulses for the exposure.

As mentioned in the review article in Applied Optics 22 (1983) p. 215-232, hereinby included by reference, it is possible to assure spatial coherence and the desired small time coherence by other means than short pulses, e.g. by

special multimode laser equipment. It is intended that also such analogues to short pulse length can be used for the invention.

References:

1. N. Abramson, "The making and Evaluation of Holograms", (Book by Acedemic Press, London 1981), pages 70-109.

2. Same as Ref. 1. pages 293-313.

3. N. Abramson, "Light-in-flight Recording: High-speed Holographic Motion Pictures of ultrafast Phenomena", Applied Optics, Vol.22, pages 215-232. (1983).

4. N. Abramson, "Single Pulse Light-in-flight Recording by Holography", Applied Optics, Vol.28, pages 1834-1841, (1989).

5. T. Carlsson, "Three Dimensional Shape Measurement by Light-in-flight Single Line contouring", Proceeding from Holographics 1990, in Nuremberg, pages 38-44.

6. J. Giordmaine and P. Rentzepis "Two-photon excitation of Fluorescence by Picosecond Light Pulses", Appl. Phys. Lett. No 11, page 216 (1967).

Patent claims

1. A method for comparing objects by holography, wherein a laser pulse is divided into an object beam expanded for illuminating an object, and a reference beam expanded for illuminating a photographic plate receiving radiaton from the illuminated object, and the photographic plate is developed for obtaining a hologram, which is subsequently illuminated, characterized in that the laser radiation pulse is an ultrashort pulse, that the expanded reference beam is directed at an angle toward the photographic plate, that the hologram obtained is illuminated by another ultrashort laser pulse in a reconstruction expanded beam that is antiparallel to expanded reference beam, situating a comparison object at the place of the said object, for illuminating the comparison object by radiation from the hologram, and focusing scattered radiation coming from the illuminated comparison object toward a light detector for obtaining an electrical pulse indicating fit of comparison between the object and the comparison object.

2. A method of claim 1, wherein said object beam is emitted towards different points on the object to be tested with such individual timedelays that they in the form of scattered diffuse light, if the object has the proper shape, all arrive at the same time to a certain point in space.

3. A method of claim 1, wherein the shortness of the said electrical pulse scattered from the object is used as a measure of the dimensional difference between the object and the comparison object.

4. A method of claim 1, wherein the light detector comprises a photodiod, photomultiplicator, kerrcell, pockelcell, nonlinear material, autocorrelater, streakcamera, light-inflight or the like.

5. A method of claim 1, wherein said detector is arranged at the point from which the object was illuminated during recording of the hologram.

6. A method of claim 1, wherein the single pulse is replaced by a number of short pulses.

7. A method of claim 6, wherein the number of short pulses of claim 7 comprises random pulses of light of short coherence length.

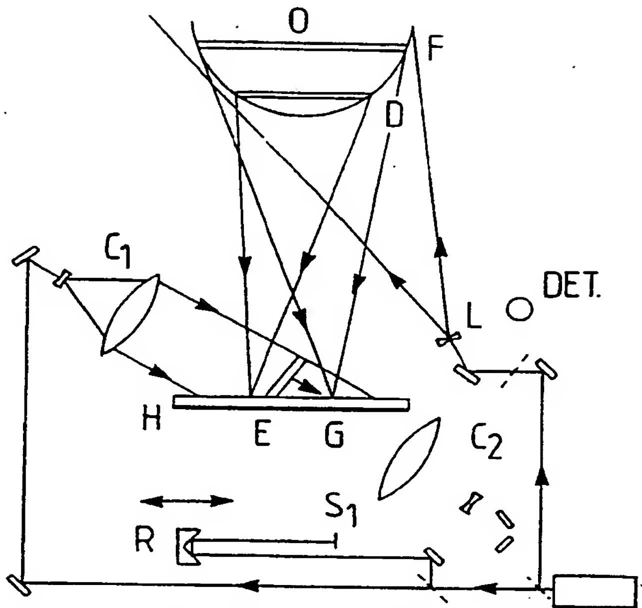

FIG.1

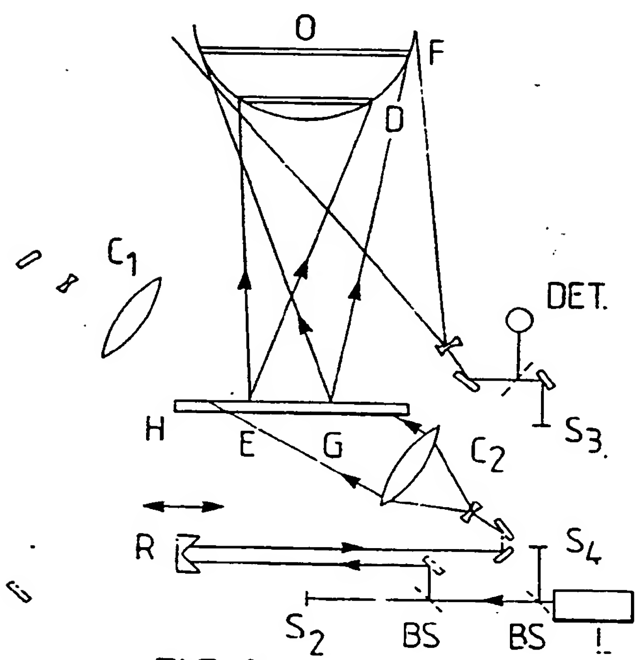

FIG.2

INTERNATIONAL SEARCH REPORT

International Application No PCT/SE 92/00120

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC5: G 01 B 9/021

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
IPC5	G 01 B, G 01 H, G 03 H

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in Fields Searched[8]

SE,DK,FI,NO classes as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category *	Citation of Document,[11] with indication, where appropriate, of the relevant passages[12]	Relevant to Claim No.[13]
A	APPLIED OPTICS, Vol. 28, No. 10, May 1989 N.H. Abramson et al: "Single pulse light-in-flight recording by holography", see page 1834 - page 1841 see the whole article (cited in the application) --	1
A	APPLIED OPTICS, Vol. 22, No. 2, January 1983 N. Abramson: "Light-in-flight recording: high-speed holographic motion pictures of ultrafast phenomena", see page 215 - page 232 see the whole article (cited in the application) --	1

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* Special categories of cited documents:[10]

"A" document defining the general state of the art which is not considered to be of particular relevance

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
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